Travelling perturbations in sheared flows: sudden transition infrequency and phase speed asymptotics

Travelling perturbations in sheared flows: sudden transition in frequency and phase speed asymptotics

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We present recent findings concerning angular frequency discontinuities in the transient evolution of three-dimensional perturbations in two sheared flows, the plane channel and the wake flows. By carrying out a large number of initial-value problem simulations[1,2] we observe a discontinuity which appears toward the end of the perturbation transient life. Both the frequency, ω, and the phase speed, $\mathbf{C}$, decrease to zero when ϕ, the angle of obliquity between the perturbation and the base flow, approaches $\pi/2$.

A few examples of transient of the frequency are reported in Fig. 1(a-b) for the channel and wake flows, respectively. When the transient is close to the end, the angular frequency suddenly jumps to the asymptotic value, which is in general higher than the transient one. The relative variation between the transient and asymptotic values can change from a few percentages to values up to 30−40%. Whenever it occurs, the emergence of a frequency discontinuity can be considered as a particular range of the temporal evolution which separates the transient (algebraic) dynamics from the asymptotic (exponential) regime. Within this temporal range, the perturbation suddenly changes its behavior by increasing its phase velocity. Independently to what observed for the amplification factor, one can assume that beyond this temporal instant the asymptotic state sets in.

The investigation of the dispersion relation, $\mathbf{C}(k)$ (see an example in Fig. 1c for the channel flow case), reveals that longitudinal short waves are non-dispersive ($\mathbf{C} \sim$ const as k is large enough), while longitudinal long waves and all the perturbations not aligned with the base flow present a dispersive behavior ($\mathbf{C}$ varies either with the angle of obliquity, ϕ, or the polar wavenumber, k). Moreover, orthogonal waves ($\phi = \pi/2$), which can experience a quick initial growth of energy, are standing waves ($\mathbf{C} = 0$). This result can be explained in terms of the system symmetry. A possible interpretation for the morphology of turbulent spots[3,4] can be drawn in the case of wall flows.

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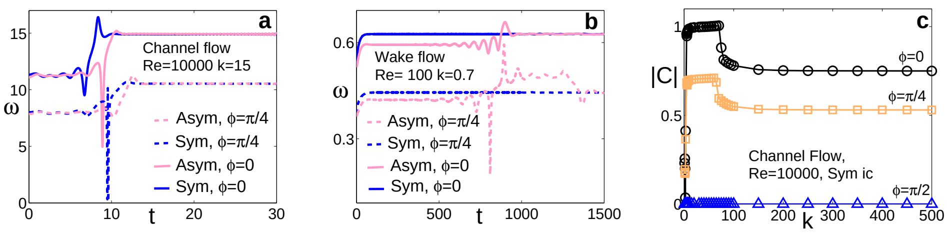

Figure 1: (a)-(b) Temporal evolution of the angular frequency, ω: (a) channel flow, (b) wake flow. (c) Asymptotic spectral distribution of the phase velocity amplitude, $|\mathbf{C}|$, channel flow.